

APPENDIX III

Estimating the Lowering of the Seepage Line in Pervious Upstream Embankment Zones During Reservoir Drawdown

1. General. In stability analyses of pervious embankment slopes subjected to various time rates of drawdown, it is often desirable to construct flow nets for use in determining seepage forces. To construct such flow nets, it is necessary to determine the lowering of the intercept of the line of seepage at the face of the impervious core. The lowering of the seepage line can be estimated as shown in a method by Schnitter and Zeller¹⁰ that relates fill permeability and drawdown rate. This relation is valid only in materials such as sands and gravel which do not change volume as the water content changes during drawdown.

2. Mathematical Relation. The equations for the dimensionless height ratio X (i.e., the ratio of height of saturation line at face of core at end of drawdown expressed in percent of drawdown) and the dimensionless parameter P_D are

$$X = \frac{H_D - \Delta H_D}{H_D} \times 100$$

$$P_D = \frac{k}{n_e V}$$

where

H_D = height of drawdown

ΔH_D = change in height of saturation line at face of impervious core

k = coefficient of permeability of shell material

$n_e = \frac{n}{100} \times \frac{w_1 - w_2}{w_1}$ = effective porosity; i.e., the ratio of void space drained to unit volume of soil where n is porosity, w_1 is saturated water content, and w_2 is water content after drainage

V = velocity of pool drawdown

1 April 1970

All quantities should be expressed in consistent units.

3. Computations. Although the curves presented in plate III-1 were developed for the case of full reservoir drawdown, they may also be used when drawdown is to some intermediate pool level above the embankment base by considering the intermediate pool elevation as the base of the embankment. The following example illustrates the use of the chart in plate III-1.

a. Assume a 105-ft-high dam with a narrow central impervious core and a 1-on-3 upstream slope. The pool is 100 ft above the embankment base and is to be drawn down 60 ft in 30 days. The shell is assumed to be a sandy gravel having a permeability of 500×10^{-4} ft per min and a porosity of 20 percent. The average saturated water content is 12 percent, and after drainage the water content is 3 percent.

The effective porosity n_e is

$$n_e = \frac{12 - 3}{12} \times \frac{20}{100} = 0.15$$

The velocity of pool drawdown V is

$$\frac{60 \text{ (ft)}}{30 \times 24 \times 60 \text{ (min)}}$$

$$V = 0.00139 \text{ ft per min} = 13.9 \times 10^{-4} \text{ ft per min}$$

$$P_D = \frac{k}{n_e V} = \frac{500 \times 10^{-4}}{0.15 \times 13.9 \times 10^{-4}} = 240$$

From the chart, for a 1-on-3 slope, $X = 10$ percent. Solving the equation

$$\frac{X}{100} = \frac{H_D - \Delta H_D}{H_D} \text{ for } \Delta H_D$$

$$\frac{10}{100} = \frac{60 - \Delta H_D}{60} \text{ or } \Delta H_D = 54 \text{ ft}$$

Thus, the height of saturation at the core is 54 ft below the original pool level, or 46 ft above the base of dam, or 6 ft above the lowered pool.

b. Assume the same conditions except that the shell is constructed of less pervious soil with $k = 5 \times 10^{-4}$ ft per min and the water content after drainage is 9 percent.

$$n_e = \frac{12 - 9}{12} \times \frac{20}{100} = 0.05$$

$$P_D = \frac{5 \times 10^{-4}}{0.05 \times 13.9 \times 10^{-4}} = 7.2$$

A value of X equal to 51 percent is obtained from the curve in plate III-1 for a 1-on-3 slope. Solving for ΔH_D

$$\frac{51}{100} = \frac{60 - \Delta H_D}{60} \text{ or } \Delta H_D = 29.4 \text{ ft}$$

In this case, the height of saturation is 29.4 ft below the original pool or 70.6 ft above the base of the dam, or 30.6 ft above the lowered pool.

4. Limitations. The curves in plate III-1 give only approximate criteria for determining the rate of drainage of shell material and lowering the line of seepage at the face of central core embankments. Judgment must be used in determining probable velocity of drawdown, and reasonable values of n_e and k . Information given by Terzaghi and Peck¹¹ may be used as a guide in selecting values of n_e . In order for values of X to approach 0 percent (i.e. complete, virtually instantaneous drainage of the shell material), the shell must approach a highly pervious condition.

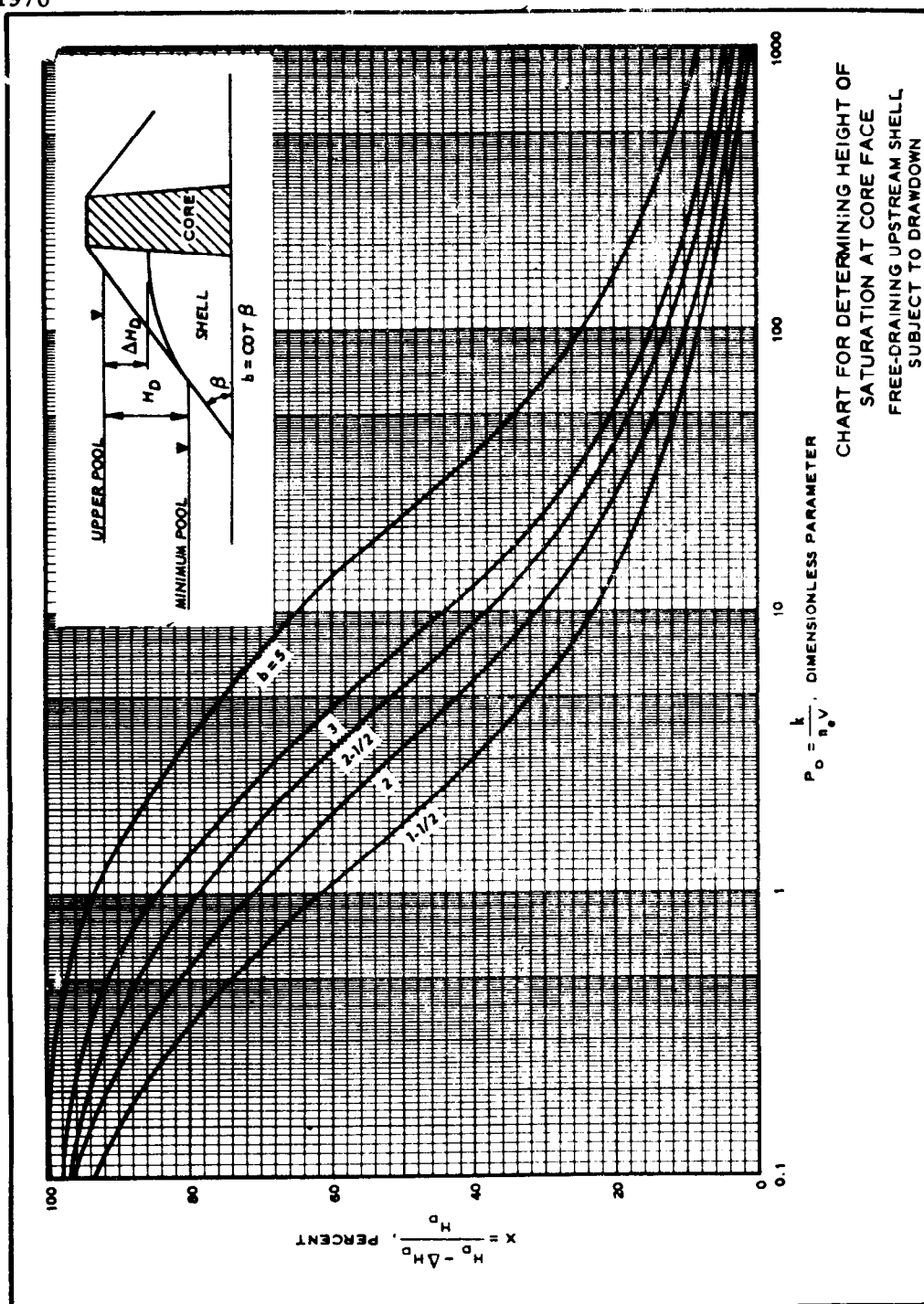


Plate III-1